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Trinh X. Thuan

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P.O. Box 3818  
Charlottesville VA 22903-08188. PERFORMING ORGANIZATION  
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Attn Dr Henry Radoski  
AFOSR NL  
110 DUNCAN AVE SUITE B115  
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The far infrared properties of normal, non-infrared-bright galaxies were studied as a function of their morphological type using a sample of 1544 galaxies of magnitude less than 14.5. Most of the far infrared color trends as a function of galaxian morphological type can be reproduced by dust models with three components, combined with an appropriate dust heating spectral energy distribution. Work has been done on the use of far infrared luminosity as a star formation indicator in galaxies. The trends observed are consistent with a two-component model, with the cirrus fraction as the second parameter and the star formation rate as the first parameter. Observations have been made and studies performed on dwarf and low surface brightness galaxies and starburst galaxies at intermediate red shifts.

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Principal Investigator: Trinh X. Thuan

Graduate Students: Richard J. Patterson and David T. Frayer

Publications (with acknowledgements to the above grant's support)

1. Schneider, S. E., Thuan, T. X., Mangum, J. G., & Miller, J. 1992. "Northern Dwarf and Low-Surface-Brightness Galaxies. II. The Green Bank Survey". ApJS, 81, 5-33.
2. Sauvage, M. & Thuan, T. X. 1992. "On the Use of  $L_{\text{FIR}}$  as a Star Formation Indicator in Galaxies". ApJ. 396, L69-L73.
3. Thuan, T. X., Patterson, R. J., Condon, J. J. & Mitchell, K. J. 1992, "Blue Galaxies Identified with Submillijansky Radio Sources in the 1300 - 3034 Field", AJ, 104, 1331-1338.
4. Patterson, R. J. & Thuan, T. X. 1992. "Tidal Interaction Between a Stripped Dwarf Irregular and a Giant Elliptical Galaxy". ApJL, 400, L55-L58.
5. Thuan, T. X. 1992, "Dwarf and Low-Surface-Brightness Galaxies", in Physics of Nearby Galaxies: Nature or Nurture?, eds. T. X. Thuan, C. Balkowski and J. T. Van (Paris: Editions Frontieres) (in press).
6. Thuan, T. X. & Sauvage, M. 1992. "The Far-Infrared Properties of Galaxies Along the Hubble Sequence", in Physics of Nearby Galaxies: Nature or Nurture?, eds. T. X. Thuan, C. Balkowski and J. T. Van (Paris: Editions Frontieres) (in press).
7. Sauvage, M. and Thuan, T. X. 1992. "The Far-Infrared Properties of the CfA Galaxy Sample. II. Gas, Dust and Star Formation Along the Hubble Sequence", submitted to Ap. J.

Books

- 1) "An Astrophysicist", published by Beauchesne-Fayard Editions (1992).

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- 2) "The Fate of the Universe: The Big Bang and After", published by Editions Gallimard (1992). The English translation will be published in the US (1993) by Abrams, in the UK (1993) by Thames and Hudson. An Italian translation will be published (1993) by Editions Electa, and a German translation will be published (1993) by Editions Ravensburger.
- 3) I am presently going over the American translation of my book "The Secret Melody", which will be published in 1993 by Oxford University Press. A German and Spanish translation are in preparation.
- 4) I co-edited the book which contained the proceedings of the international meeting on "Physics of Nearby Galaxies: Nature or Nurture?", which I co-organized. The book is to appear in March 1993.

#### Research Highlights

1. The Far-Infrared Properties of Galaxies Along the Hubble Sequence  
(publications 6 and 7)

In collaboration with M. Sauvage, the FIR properties of normal, non-infrared-bright galaxies along the Hubble sequence are studied as a function of their morphological type, using a complete sample of galaxies in the magnitude limited ( $m_{\text{Zwicky}} < 14.5$ ) CfA sample detected in the Faint Source Survey, a total of 1544 galaxies. We found that the short-wavelength FIR emission is best explained as having mainly an interstellar origin, and not as coming mostly from non-thermal sources or from circumstellar or photospheric emission from evolved stars. The FIR colors of galaxies from type E-S0 to type Sbc, are mainly controlled by the spatial distribution of the dust relative to the stars. The dust in elliptical galaxies is as hot as in magellanic irregulars, because it is concentrated in their central regions ( $r \leq 1$  kpc) where the UV energy density from post-AGB stars is the highest. The dust in Sbc galaxies is the coolest because it is most spread out in the disk

where the UV energy density is the lowest. From type Sbc to type Sbm, the FIR colors are controlled by an increasing star formation efficiency, modulated by a change in dust composition. The metallicity decrease in Sdm galaxies leads to a deficiency of small grains relative to large grains and a reduction of the dust and  $H_2$  masses relative to the HI masses. Conversely, in elliptical galaxies, the larger metallicity may increase the abundance of small grains relative to large grains. Most of the FIR color trends as a function of galaxian morphological type can be reproduced by dust models with three components (PAHs, intermediate-size and large grains), combined with the appropriate dust heating spectral energy distribution.

2. On the Use of Far-Infrared Luminosity as a Star Formation Indicator in Galaxies (publication 2, reprint enclosed)

By comparing the  $H\alpha$  and far-infrared (FIR) luminosities for an optically selected magnitude-limited ( $m_B \leq 14.5$ ) sample of galaxies, we have found a strong nonlinearity in the  $\log L_{H\alpha} - \log L_{FIR}$  correlations, and a systematic decrease of the  $L_{FIR}/L_{H\alpha}$  ratio from early- to late-type spirals. We show that these trends cannot be interpreted in the frame of a single-component model for the FIR emission of galaxies, with the star formation rate as the only parameter, but are consistent with a two-component model, with the cirrus fraction as the second parameter. We found a decreasing contribution of the cirrus component to  $L_{FIR}$  toward later types, going from ~86% for Sa galaxies to ~3% for Sdm galaxies. If  $L_{FIR}$  is to be used as a star formation indicator in galaxies, it needs to be corrected, to first order, for the cirrus component, taking into account the morphological type of the galaxy. This work was done in collaboration with Marc Sauvage.

3. Studies of Dwarf Galaxies (publication 1, 4 and 5)

In collaboration with S. Schneider (U. Mass.), I published the results

of the neutral hydrogen survey of dwarf and low surface brightness galaxies done with the NRAO 300 ft radio telescope at Green Bank (publication 1).

With graduate student R. J. Patterson, I have studied in detail the case of a dwarf galaxy which has lost its gas by ram-pressure stripping and which is tidally interacting with a large elliptical galaxy (publication 4).

4. Studies of Starburst Galaxies (publication 3)

In collaboration with graduate student Richard J. Patterson and J. Condon (NRAO), I have obtained deep CCD pictures with the 4m Kitt Peak telescope, to optically identify very weak sub mJy radio sources. The CCD photometry in conjunction with galactic evolution models shows that these very faint radio sources are associated with starburst galaxies at intermediate redshifts.

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